Assessing combination traps: using risk to define uncertainty

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Abstract

Probabilistic assessment of exploration prospects comprises two processes: estimation of risk, and estimation of uncertainty. Risk, $R$, is the chance of failure, while $1-R$ is the chance of success. Uncertainty is the range of volumes, and their associated exceedance probabilities, that we may encounter if we are successful. The chance of success is often impacted by the trap type. Fault-dependent closures are usually perceived as having lower chances of success than fault-independent closures. Combination traps, i.e., traps that are both fault-independent and fault-dependent, require a blurring of the distinction between uncertainty and risk. The chance of success for each trap type is used to define the uncertainty within the success case. In order to create the success case distribution of potential contacts in a combination trap, one must consider the chance of success for each individual trap type. Geologists who do not consider risk when assessing uncertainty may create success case distributions that cannot be technically supported.

Risk versus uncertainty

Probabilistic assessment of exploration prospects comprises two processes: estimation of risk and estimation of uncertainty. The estimations of risk and uncertainty are often regarded as two separate, unrelated calculations. But when assessing combination traps the distinction is blurred as the risk on individual trap types is used to define the uncertainty for the overall prospect.

To an explorationist, risk, $R$, is the chance of failure. But being optimists, explorationists usually refer to the chance of success, which is $1-R$. Chance of success (COS), also known as geological chance of success (POG, Pg, or Ps), is the probability that an exploration prospect will contain a resource volume that is potentially producible and is large enough to be classified as a sub-economic field or discovery (Otis and Schneidermann, 1997; Rose, 2001; Jordanov et al., 2006). Shows and insignificant accumulations are considered failures. The line that separates success from failure is fuzzy and varies widely from company to company. But the division is just meant to separate the volumes that are geologically significant, in a given play, from those that are not (White, 1993).

To estimate the chance of success, the explorationist considers several geological risk factors such as trap size, seal capacity, reservoir, source, and migration, and estimates the probability that each factor is adequate to support the minimum volume required for success (Megill, 1984). The value assigned to each risk factor is its chance of adequacy, and the product of these values is the chance of success. Although risk is the chance of failure, when we assess we estimate the probability of success. Our use of the term risk is technically incorrect, given that we are actually estimating the probability of success, but the terminology has become hopelessly embedded in our assessment practices.

Uncertainty is the range of volumes, and the associated probabilities that those volumes will be exceeded (their associated exceedance probabilities), that we may encounter if we are successful. The probabilities are conditional in that they assume success. Assuming success, the P100 volume defines the smallest possible volume of hydrocarbons in the prospect: we have 100% chance of finding more than the P100 volume. The chance of success is the unconditional probability that we will find more hydrocarbons than the P100 volume. Risk, the chance of failure, is the probability that we will encounter a volume that is smaller than the P100. We assume that the failures have a resource volume of zero. Although this is not true – virtually every well drilled in a sedimentary basin probably encounters at least microscopic quantities of hydrocarbons – we are uninterested in attempting to assess volumes that are not successful.

Together, the risk and the uncertainty account for all possible outcomes of an exploration prospect (Figure 1). The success case curve graphs the uncertainty. Commonly cited cases, such as the P90, P50, and P10, refer to points on the success case curve. The risked curve transforms the success case’s conditional probabilities to unconditional exceedance probabilities, and includes the probability of failure. Typically, explorationists assess the success case, and then create the risked case by multiplying the success case probabilities by the chance of success (White and Gehman, 1979).

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Combination traps
The prospect’s chance of success is partially a function of the trap type and its associated seal capacity. In most plays, stratigraphic traps are riskier, or less likely to seal, than structural traps. Fault-dependent traps are less likely to seal than fault-independent traps. The term ‘combination trap’ refers to a closure formed by two or more different trap or seal types: structural and stratigraphic traps (Levorsen, 1967), fold and fault traps (Biddle and Wielchowsky, 1994), seals against different lithologies, or any other combination of trapping or sealing mechanisms.

Many explorationists mistakenly assume that the chance of success must incorporate the chance on each individual trap type. But, in most cases, only the structurally highest trapping mechanism impacts success or failure. Seal in the highest trap insures that the prospect will contain hydrocarbons, assuming that other geological elements are adequate, while lack of seal in the highest trap results in a dry structure. The risks associated with structurally lower traps cannot impact the prospect’s chance of success. Failure of a lower trap may limit the success case volume, but will not result in a dry structure.

In the example of Figure 2, we have a structure that comprises a fault-independent closure, a fault-dependent closure against shale, and a fault-dependent closure against sand. For simplicity, we will assume that the only risk is on seal capacity, and that structural capacity, reservoir, source, and migration are proven. We will also assume that the structure is fully charged. The only limitation on the oil-water contact (OWC) is success or failure of the seals in the three traps.

The evaluation begins by risking the seal of each trap type as if it is the only trap in the prospect (Figure 3). What is the chance for seal if the prospect is only a fault-independent closure? What is the chance for seal if the prospect is only a fault-dependent closure against shale? What is the chance for seal if the prospect is only a fault-dependent closure against sand?

In the fault-independent closure, we are risking the presence of top seal. When risking the fault-dependent traps, we must assume that the top seal is present. In other words, we need the conditional chance for fault seal given that the top seal is present. If we are basing our estimates on historical success rates, we must limit our analogue dataset to fault closures in which the top seal is present. Otherwise, the
chances for seal in the fault-dependent traps may be too low: the top seal risk will be included in the fault seal risk.

Let us assume that our evaluation of seal capacity yields the chances of adequacy, and corresponding risks of failure, shown in Table 1. Using these probabilities, we can calculate the probability of each possible outcome: 1) prospect failure; 2) accumulation limited to the fault-independent trap; 3) accumulation limited to the fault-independent and fault-dependent trap against shale; and 4) accumulation filled to spill. These four outcomes are referred to as scenarios. To calculate the probability of each scenario we must first ask – ‘What combination of seal success or seal failure yields each scenario?’ Then use the seal or leak probabilities in Table 1 to calculate the scenario chance.

Failure of the prospect, a dry structure, results when the top seal fails, a probability of 0.20. An accumulation limited to the fault-independent closure results when the top seal succeeds (0.80), and the fault seal against shale fails (0.50), yielding a scenario probability of 0.40.

If the top seal succeeds but the fault seal against shale fails, the structure should fill down to the base of the fault-independent trap. The OWC uncertainty distribution for the scenario should reflect our uncertainty around that depth (Figure 4). An accumulation limited to the upper two traps results when the top seal succeeds (0.80), the fault seal against shale succeeds (0.50), and the fault seal against sand fails (0.80), yielding a scenario probability of 0.32. If the top two traps succeed, and the seal against sand fails, the structure should fill down to the base of the fault-dependent closure against shale. The OWC uncertainty for the scenario will reflect our uncertainty around that depth (Figure 5).

<table>
<thead>
<tr>
<th>Seal type</th>
<th>P(successful seal)</th>
<th>P(seal failure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top seal</td>
<td>0.80</td>
<td>1-0.80=0.20</td>
</tr>
<tr>
<td>Sand against shale</td>
<td>0.50</td>
<td>1-0.50=0.50</td>
</tr>
<tr>
<td>Sand against sand</td>
<td>0.20</td>
<td>1-0.20=0.80</td>
</tr>
</tbody>
</table>

Table 1 Chance of seal (and risk of seal failure) for each trap type.

Figure 3 Risking the individual trap types.

Figure 4 OWC distribution for the fault-independent trap.
The OWC distribution of each scenario is weighted by its success case, or conditional probability. The weighted distributions are then combined to create the overall prospect uncertainty distribution for OWC (Figure 7).

**Discussion**

The described method presents an easy-to-follow framework that may be applied, with slight modifications, to any closure. It is valid for any number or variety of trap types. Once the basic calculation framework is in place, the seal chances may be easily revised as needed. The prospect’s OWC distribution may be altered simply by changing the seal probabilities on the individual traps, then calculating the success case weight of each scenario. By concentrating on the seal probability of the individual trap types, the

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Risked case probability</th>
<th>Success case probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prospect failure (risk)</td>
<td>Top seal fails = 0.20</td>
<td></td>
</tr>
<tr>
<td>OWC within fault-independent closure</td>
<td>Top seal succeeds = 0.80</td>
<td>0.40 / 0.80 = 0.50</td>
</tr>
<tr>
<td>OWC within fault-dependent closure against shale</td>
<td>Top seal succeeds = 0.80</td>
<td>0.32 / 0.80 = 0.40</td>
</tr>
<tr>
<td>OWC within fault-dependent closure against sand</td>
<td>Top seal succeeds = 0.80</td>
<td>0.08 / 0.80 = 0.10</td>
</tr>
<tr>
<td>Total</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*Table 2 Calculation of risked and success case probabilities.*
The geoscientist creates a technically supportable OWC distribution that should reflect the contact distributions observed in similar closures.

The method may be used to define seal capacity independently of charge volumes. Once the seal framework is defined, the charge volumes may be added to the prospect. The final OWC uncertainty will be a function of seal capacity uncertainty, charge uncertainty, and uncertainty of hydrocarbon pore volume capacity within the trap.

The method assumes that the geologist has sufficient knowledge and ability to evaluate the seal risk on the individual trap types. This could include the construction of Allan diagrams, the analysis of historical data, or seal capacity calculations. Although a large body of local data may not be available in all plays, the numerous studies of seal capacity from plays around the world should allow the geoscientist to make an educated guess regarding the seal chances in even the most remote, frontier play.

The assessment of complex traps requires a complex solution. Taking shortcuts, or falling back on the traditional assessment practices of 20 years ago, will result in a probabilistic assessment that bears little or no relationship to the prospect actually described by the geoscientist.

References


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